PACKAGED PHASAR-BASED WAVELENGTH DEMULTIPLEXER WITH INTEGRATED DETECTORS

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ABSTRACT

For the first time, PHASAR-based wavelength demultiplexers with integrated detectors have been packaged in an industry-standard Butterfly-type module. 8-Channel nearly polarisation-independent operation is demonstrated. In addition, 4nm tuning is realised.

I. INTRODUCTION

The quickest growing market segment in optical telecommunications is that of Wavelength Division Multiplexing (WDM) systems. Presently, these systems find are deployed in high-end point-to-point links, and are constructed from discrete components such as wavelength-specific DFB lasers, modulators, (de-)multiplexers, and receiver photodiodes. As the number of installed WDM systems grows, this technology will penetrate further into the network, which will call for a reduction of the number of separate components, in favour of cost-effective integrated solutions.

On the receiver side of a WDM link, a single module containing a wavelength demultiplexer, photodetectors, and transimpedance amplifiers, is an attractive component. Recently, a number of wavelength demultiplexers with integrated photodetectors have been reported [1], [2], [3], [4], [5]. In addition, both hybrid [6] and monolithic [7] integration of a PHASAR and preamplifiers have been shown, as well as a packaged WDM receiver module containing a pigtailed spectrograph and a separately pigtailed pin-JFET array [8].

In this paper, the first packaged InP PHASAR-based demultiplexer with integrated detectors is presented, using an industry-standard Butterfly module. This is made possible by the compact dimensions of the opto-electronic chip. Nearly polarisation-independent CW operation is demonstrated for 8 channels with 200GHz spacing. In addition tuning of the channels is realised over 4nm.

II. DESIGN

Polarisation-independent operation is obtained by making use of non-birefringent waveguides [9]. The 8×8 PHASAR chip, shown in Fig. 1, is designed to have a central wavelength of 1535nm, a 200GHz channel spacing, and a 50nm free spectral range. Its size is only $1.4 \times 1.3\text{mm}^2$. To transfer light from the output waveguides to the InGaAs absorption layer, evanescent coupling is employed in the detectors. Using the optimised layer stack shown in Fig. 2, simulation work predicts a better than 99% coupling efficiency in the 200 μm long, 8 μm wide detectors.

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Fig. 1. PHASAR with integrated detectors.

Fig. 2. Photodetector layers.

III. FABRICATION

After Low-Pressure MOVPE growth, processing starts with definition of the detector mesas using selective wet chemical etching. In the same step, the detector layers are removed from the area designated for the PHASAR. Outside this area the detector layers are left in place to absorb scattered light. Next the p-metallisation is fabricated, which consists of $6\mu\text{m}$ wide strips on top of the detector mesas, connected to $100 \times 100\mu\text{m}$ wide bond pads by $10\mu\text{m}$ wide leads. Prior to deposition of the metallisation, a Si_3N_4 isolation layer is deposited. Fabrication of the PHASAR is performed by means of direct electron-beam writing techniques and reactive ion etching. Finally, the wafer is thinned and the n-metallisation is deposited.

The wafer is cleaved into dies of $3.5 \times 3\text{mm}^2$, and an AR coating is applied to the front facet. Subsequently, the device is mounted on a Si submount and a $6 \times 6\text{mm}^2$ carrier with 8 contacts. Fibre-chip coupling is accomplished by means of a lensed fibre, having a $12.5\mu\text{m}$ radius of curvature allowing less than 1dB coupling loss. The fibre is actively aligned to the appropriate input waveguide, and fixed by soldering it on a stud mounted on a base plate in front of the carrier. Finally, the fibre-chip assembly is mounted on a Peltier cooler inside a 14-pin industry-standard Butterfly package (see Fig. 3).

IV. RESULTS

Figure 4 shows the response at 1mW unpolarised input power of an 8-channel device before and after packaging. (Before packaging, data were obtained by positioning a lensed fibre—different from the one used in the module—in front of an input waveguide using a piezo controlled X-Y-Z translation stage.) The performance of the module is only 1dB below that of the unpackaged device, which can be attributed to a larger coupling loss in the module. For six channels, the crosstalk is below -20dB , one channel has a low response, and another one has a high background. This is due to an electrical leakage path from the detector bond pad to the absorber regions surrounding the PHASAR. Finally, all channels have a TE-TM shift of less than 0.2nm.

This device has a rather large insertion loss of 21dB, as is determined from Fig. 4 by assuming a detector with 100% internal quantum efficiency. This is accounted for by the 8dB insertion loss of the PHASAR (which is measured from a device which had the detectors cleaved off), and the -13dB external efficiency of the detector (which is obtained

Fig. 3. 8-Channel Butterfly-type PHASAR module.

Fig. 4. Photo current versus wavelength at 1mW input power, before (left) and after packaging (right). The channel spacing is 200GHz, as designed.

from the array of detectors cleaved off the PHASAR). The low efficiency of the detectors has been tracked down to a problem with the Si_3N_4 isolation layer, which breaks down at reverse voltages above 1V. In addition, this problem is responsible for the large background of one of the channels. Separately fabricated reference photodiodes having a good Si_3N_4 layer exhibit an external efficiency of -3dB at a reverse voltage of 5V, including coupling and waveguide loss.

In addition to the 8-channel polarisation independent device, one of the devices reported in Ref. [3] has been packaged as well. As shown in Fig. 5, tuning over more than 4nm has been obtained with virtually no performance degradation, by changing the chip temperature using the built-in Peltier cooler.

V. CONCLUSIONS

First results have been presented of PHASAR-based wavelength demultiplexers with integrated photodetectors which are packaged in industry-standard Butterfly-type modules. 8-Channel nearly polarisation-independent operation has been demonstrated, as well as tuning of the channels over more than 4nm.

Fig. 5. Photo current versus wavelength at 1 mW input power for 1 channel at 3 temperatures.

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